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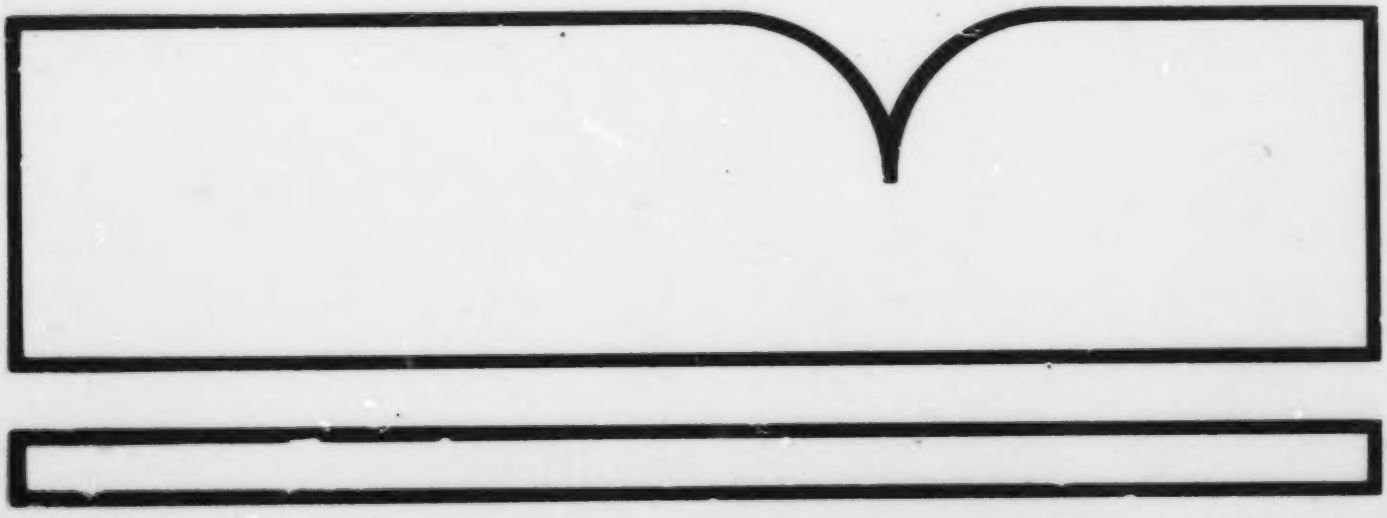

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16. ABSTRACT The paper describes the integration of quality assurance (QA) into each phase of radon mitigation: initial problem assessment, premitigation diagnostics, mitigation system specification and installation diagnostics, and post-mitigation diagnostics. During each phase, the interests and responsibilities of the different parties (individuals, companies, and governments) must be understood in order to ensure the quality of the installed mitigation system. Residential radon reduction requires that houses be individually evaluated to identify the source(s) of radon, to select an appropriate mitigation technique, to design the mitigation system, and to confirm that the installed system is effective. A variety of measurements in addition to radon levels may be necessary to accomplish these objectives. QA practices and quality control (QC) procedures can be applied to ensure that sufficient information of known quality is available to make design decisions and that the final system is properly installed, safe, and effective.

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PLANNING FOR QUALITY IN RADON MITIGATION

PB90-262940

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ABSTRACT

Residential radon reduction requires that houses be individually evaluated to identify the source(s) of radon, to select an appropriate mitigation technique, to design the mitigation system, and to confirm that the installed system is effective. A variety of measurements in addition to radon levels may be necessary to accomplish these objectives. Quality assurance (QA) practices and quality control procedures can be applied to ensure that sufficient information of known quality is available to make design decisions and that the final system is properly installed, safe, and effective. This paper describes the integration of QA into each phase of radon mitigation: initial problem assessment, pre-mitigation diagnostics, mitigation system specification and installation diagnostics, and post-mitigation diagnostics. During each phase, one must understand the interests and responsibilities of the different parties (individuals, companies, and governments) in order to ensure the quality of the installed mitigation system.

INTRODUCTION

An understanding of the different phases of a radon mitigation project, as well as of the roles (interests and responsibilities of different parties) during each phase, is important in deciding who will measure what and when. Radon mitigation may be divided into four phases:

1. Initial problem assessment
2. Pre-mitigation diagnostics
3. Mitigation system specification and installation diagnostics
4. Post-mitigation diagnostics

This paper will review the activities associated with each phase and discuss the integration of quality assurance into those activities. Qualitative objectives may be specified for each phase (e.g., the steps to be completed before proceeding to the next phase, the types of materials to be used, and standard operating procedures for sampling or measurement). Quantitative objectives may be set for the measurements performed during each phase. These include minimum detection limit, precision, and bias.

Several parties (homeowners, companies, governments, and possibly home buyers) with different interests and responsibilities may be involved in radon mitigation. State governments are responsible for protecting the public health. States may run screening programs to identify problem houses, license measurement and mitigation consultants, and provide for long-term monitoring after mitigation. Homeowners are concerned about their health and the health of their families. In most cases, homeowners are responsible for the cost of radon mitigation and for any long-term maintenance or monitoring of the mitigation systems.

A special situation occurs when a house is being sold -- the home buyer's primary concern is health effects, while the homeowner is more concerned with the cost of mitigation and the effect on property value. The need for quality assurance increases when the results of a measurement may force one party to pay for something which benefits another party. Real estate companies may require measurements by a radon measurement specialist, rather than the homeowner. In some states, this specialist may not be allowed to mitigate the house should the measurements show unacceptable radon levels.

Typically an elevated radon level will cause the homeowner to call in a radon mitigation consultant. The consultant will discuss house characteristics and occupancy patterns with the homeowner, inspect the house, make diagnostic measurements, and recommend a mitigation system. Since each house is unique, each must be treated individually. Certain types of mitigation systems tend to work in certain types of houses, but an on-site inspection by the consultant is always necessary. Often the system is installed by an employee of the consultant. After installation, the consultant will inspect the system to ensure that it meets specifications and craftsmanship standards. Additional radon measurements should be made to show that levels have been reduced satisfactorily. When the effectiveness of the mitigation system has been confirmed, each interested party should receive a written report from the consultant. The mitigation consultant bears the primary responsibility for quality assurance in radon mitigation, but the other parties should be familiar enough with the principles and practices that they know what to expect.

Appropriate planning and documentation of quality assurance (QA) and quality control (QC) activities provide confidence that a product or service will satisfy identified needs. A QA plan is a written statement of an organization's experience, capabilities, and approach to implementing both QA and QC in its normal operations. QA activities include defining appropriate measures of quality, setting objectives for those measures, and specifying operating procedures capable of meeting those objectives. Perhaps the most important QA activity is documenting what was planned, what was actually done, how it was done, and how well it was done. QC activities are more specific. They verify that the specified procedures are being followed and monitor the defined measures of quality to confirm that the QA objectives are being met.

When applied to radon mitigation, QA practices and QC procedures can ensure that sufficient information of known quality is available to make design decisions and that the final system is properly installed, safe, and effective. As an example, often the mitigation consultant has to choose among alternative measurement methods or mitigation techniques. Performance capabilities, as well as cost and convenience, should be considered. Although the chosen measurement method or mitigation technique may not have the best available performance, it should be adequate to meet the identified needs.

INITIAL PROBLEM ASSESSMENT

The first step is to determine what problem to assess. Although the health risk of indoor radon is lung cancer, the motivation for mitigation decisions is often a house sale which is contingent upon an "acceptable" radon measurement. The EPA estimates that 20,000 lung cancer deaths per year in the U.S. may be related to radon exposure [1]. The EPA's action level for radon mitigation was set at 148 Bq/m^3-yr (4 pCi/L-yr) based on an assessment of what mitigation technology could achieve, not on an "acceptable" risk. If one received this exposure for 70 years, one's probability of getting lung cancer would be about 2%. Risk assessments by the National Council on Radiation Protection (NCRP), the National Academy of Sciences (NAS), and the EPA assume a linear dose-response relationship with no "threshold" exposure below which the risk disappears. Thus the risk due to exposure at 37 Bq/m^3 (1 pCi/L) is 10% of the risk due to exposure at 370 Bq/m^3 and 1% of the risk due to exposure at 3700 Bq/m^3.

When a real estate transaction is contingent upon a radon measurement, the EPA action level often becomes a threshold value. Although the risk of cancer from exposure to 140 Bq/m^3 is 90% of the risk from exposure to 155 Bq/m^3, many people perceive the action level as a distinct boundary between safe and unsafe houses. For radon measurement specialists, it is probably not worth getting into this issue if the house is being sold. It may be worth discussing in other circumstances (e.g., the homeowner expresses concern about the health of children living in the house). Thus, the specialist should determine whether the EPA action level is a threshold value for the homeowner.

The performance of radon detectors should be documented by their vendor. Successful participation in EPA's Radon Measurement Proficiency Program is a minimum standard of performance. Users of large quantities of detectors should request a copy of the vendor's QA plan. Measurement specialists should know the precision and bias of the radon detectors which they use for problem assessment, particularly near the action level. Specialists should use blank and spiked detectors to check for bias and co-locate at least 10% of detectors to evaluate precision under field conditions. Placement of radon detectors should conform to EPA guidelines [2] and be well documented.

The EPA's recommended action level for radon is an annual average value, but few radon measurements actually span a full year, especially problem assessment measurements. Indoor radon levels vary both seasonally and with the passage of weather fronts. Annual averages may be predicted from short-term measurements, but the accuracy of the prediction is poorer than the accuracy of the measurement and depends on the season of measurement. Two types of radon measurements should be made before a house is considered for mitigation [2]. If the first, quick measurement indicates a possible problem, additional, longer measurements should provide a more accurate assessment of radon levels. The former are screening measurements; the latter, follow-up.

Screening measurements of indoor radon typically span a period of a few days to a few weeks, depending on the type of detector. These measurements should be made in a closed house with minimum ventilation so that radon levels will represent the maximum potential exposure in the house. These conditions

normally exist when the average outdoor temperature is less than 4°C (40°F), but may be difficult to ensure in other seasons. When assessing the significance of short-term measurements, the time of year that they were made should be considered. In most of the U.S., indoor radon levels are highest in the winter: when the heating system is operating, the house is closed, and indoor-outdoor temperature differences are maximized.

Follow-up measurements should be made if the initial screening measurement indicates an unacceptable radon level. These measurements should span a period of at least 2 weeks [3], unless the initial screening measurement was over 7400 Bq/m^3 (200 pCi/L). Follow-up measurements should be made at the same location as the screening measurement and in at least one other living area. When there are living areas on other levels, measurements should be made there, also. If these measurements confirm the unacceptable radon levels, mitigation should be considered. A professional radon mitigation consultant should be hired to select a mitigation system and supervise its installation. When selecting a consultant, the homeowner should consider whether he or she has state or federal certification. The homeowner may also inquire whether the prospective mitigator has a QA plan.

PRE-MITIGATION DIAGNOSTICS

Pre-mitigation diagnostics are a logically organized set of measurements and observations. They are necessary to identify how radon enters a particular structure and what mitigation techniques are likely to be successful [4]. Diagnostic measurements include radon concentrations, air pressure differences, air flows, and sub-slab communication. Design decisions should be based upon a consistent set of accurate measurements. The consultant should be familiar with the performance (precision, bias, possible interferences) of his or her measurement methods. Knowledge of these performance characteristics guides the mitigator's recognition of inconsistent measurements and proper evaluation of the other measurements.

No two houses, however similar in appearance, are alike as far as radon entry is concerned. Seemingly minor differences in construction, finishing, or soil characteristics may have a major effect on radon entry. Because of these differences, each house with high radon levels should be evaluated by an experienced radon mitigation consultant. The consultant should discuss living patterns and house characteristics with the owner, inspect the house, and make diagnostic measurements before recommending a mitigation system. The consultant should evaluate potential mitigation techniques in succession until the measurements indicate that one should work. Even when diagnostics show that the first technique evaluated will work, it is wise to consider alternative techniques. The choice of diagnostic measurements will depend on the techniques considered for a particular house. Typically the consultant will try to perform all pre-mitigation diagnostics during a single visit to the house. Since radon entry rates and routes vary seasonally, it may be difficult to predict effectiveness of mitigation systems during all seasons of the year.

MITIGATION SYSTEM SPECIFICATION AND INSTALLATION DIAGNOSTICS

After pre-mitigation diagnostics, the mitigation consultant should discuss the results with the homeowner and recommend a mitigation system. They should agree on a radon reduction goal, which may be to reduce radon concen-

trations below 148 Bq/m^3. If so, they should discuss whether this goal represents an annual or a short-term average. Alternatively the goal might be to reduce radon levels to some fraction of the pre-mitigation value. In this case, the effect of seasonal variations in radon levels should be discussed.

The consultant should specify the mitigation system in writing in sufficient detail so that it could be installed by someone else. Often the system will be installed by an employee of the mitigation consultant. System specifications include materials; location of ducts, wires, and penetrations of the building shell; controls; and operating parameters such as pressure drops and flow rates. There should be some provision for long-term monitoring of the system hardware so the homeowner can determine if it is operating normally. For example, a simple pressure or vacuum gauge could serve this purpose on a suction system. Suction systems which involve pipes or ducts through living space should have the fan located outside the building shell. Then, if leaks develop, indoor air will be sucked into the system rather than radon being forced out into the living space.

Following installation, the consultant should check the mitigation system both qualitatively and quantitatively. The system should be allowed to operate at least 24 hours before this inspection. Qualitative checks include adherence to craftsmanship standards as well as conformance with specifications. Leak tests should be performed on all joints in pipes or ducts. Exhaust pipes should terminate above the roof or at least 0.6 m (2 ft) from the house wherever possible to prevent radon re-entrainment. Because soil gas is very moist, systems which exhaust it should be designed to accommodate condensation. Quantitative checks verify that the installed system achieves the specified operating parameters. For suction systems, vacuum at the suction points and pressure drops at test holes in the slab and possibly the walls should be measured, as well as flow rates in pipes or ducts. Heat recovery ventilators should be adjusted to balance the inflow of outdoor air against the outflow of indoor air so that depressurization does not result.

Much of the air exhausted by soil suction systems comes from the space above the slab. This may increase depressurization of that space. Depressurization exceeding 6 Pa may cause reverse flow in chimneys or flues of combustion appliances. Combustion products then enter the house instead of being exhausted outdoors. This can cause chronic respiratory problems and, if the combustion process is producing abnormal amounts of carbon monoxide, possible asphyxiation. Smoke sticks may be used to evaluate airflow during cold start-up of combustion appliances [5]. It is normal for some backdrafting to occur at start-up, before the flue is filled with hot gases. If backdrafting continues for over 30 seconds, however, a potentially dangerous problem exists.

POST-MITIGATION DIAGNOSTICS

After the mitigation system has been installed, inspected, and approved by the consultant, post-mitigation diagnostic measurements should be made. The most important of these measurements are the indoor radon levels. At this stage, one generally wants immediate feedback on the effect of the mitigation system on radon levels. Short-term measurements are useful for this purpose. It is desirable, however, also to make measurements which are indicative of the annual average radon level. During the initial problem assessment, intermediate-term measurements at two locations should have been performed. Post-mitigation measurements should be made at the same locations for a minimum of 2 weeks [3]. Since acceptance of the completed system depends on these measurements, they should be made either by the measurement specialist who was

involved in the problem assessment or by both the homeowner and the consultant. In the latter case, identical detectors should be co-located and separately returned for analysis. If their relative difference exceeds 30%, the measurements should be repeated.

If the post-mitigation radon levels do not meet the goal set during system specification, the consultant will need to consider another mitigation technique or an additional radon source (e.g., water or building materials). If more pre-mitigation diagnostic measurements are necessary, the mitigation system specification, installation, and acceptance process may be repeated.

If the radon levels are marginally acceptable, the installed mitigation system may be modified to increase its effectiveness. Additional sealing may increase the strength and extent of pressure fields. A fan may be changed to increase the pressure drop or flow rate. Another suction point may be added. On the other hand, if the radon levels are well below acceptable levels, the mitigation system may be adjusted to reduce energy costs or to improve residents' comfort (e.g., reduce drafts or noise) while maintaining acceptable radon levels. The 1-month radon measurements should be repeated after any adjustment of the mitigation system. Upon completion of the post-mitigation diagnostics, all test holes used for diagnostic measurements should be permanently sealed. The residents should be advised to measure radon levels during subsequent heating seasons as long as the house is occupied in order to monitor the long-term performance of the mitigation system.

DOCUMENTATION

When the radon in the house has been reduced to an acceptable level, the mitigation consultant should provide written reports to the interested parties. The homeowner's report should contain (1) a complete description of the mitigation system, including specifications and measured operating parameters; (2) a careful explanation of controls and any indicators of system failure; (3) an outline of periodic inspections to monitor the integrity of sealants and ducts, as well as accumulation of moisture and condensation; (4) a description of any preventive maintenance; (5) a discussion of the sensitivity of the system to typical house remodeling projects (e.g., finishing the basement or replacing the heating system); (6) a description of the post-mitigation radon levels and the method by which they were measured; and (7) any warranty of the equipment or system as a whole. Finally, the report should emphasize the importance of monitoring radon levels regularly for the lifetime of the house.

If the high radon levels were originally detected by a State-government-sponsored screening program, the sponsoring agency should be notified that the house has been mitigated. Some states require reports on all mitigated houses. A report on the pre- and post-mitigation radon levels as well as the type of mitigation system installed is usually adequate. If sale of the house was the motivation for mitigation, the home buyer or realtor should receive a copy of the homeowner's report.

CONCLUSIONS

A high quality radon mitigation system does not occur just because the mitigator is competent and honest. It requires thoughtful planning, disciplined implementation, and thorough documentation. Radon mitigation companies should prepare a QA plan which specifies objectives for precision and bias of the measurements that they make, procedures to verify that those objectives

are met, and conditions for proceeding from one phase of mitigation to the next. The QA plan should also outline the documentation that will be produced during each phase and after the mitigation system is accepted by the owner.

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